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Tools and Technology

Quantifying Thermal-Imager Effectiveness for Detecting Bird Nests on Farms

MATTHEW D. STEPHENSON[1] **Department of Natural Resource Ecology and Management, Iowa State University, 2310 Pammel Drive, 339 Science Hall II, Ames, IA 50011-1031, USA**

LISA A. SCHULTE Department of Natural Resource Ecology and Management, Iowa State University, 2310 Pammel Drive, 339 Science Hall II, Ames, IA 50011-1031, USA

ROBERT W. KLAVER Iowa Cooperative Fish and Wildlife Research Unit, U.S. Geological Survey, 2310 Pammel Drive, 338 Science Hall II, Ames, IA 50011-1031, USA

ABSTRACT We conducted a designed experiment to test whether having a thermal-imaging camera available affected researchers' nest detection rates when searching for bird nests in cropland and grassland habitat in an agricultural landscape of Iowa, USA, in 2016. With known active nests present, naïve observers searched for nests with and without a thermal imager available. We did not find a difference in detection probabilities, although only a large difference would have been detectable with our sample size. Extraneous heat signatures from reflected solar radiation and dense vegetation were key factors limiting the usefulness of thermal imagers for locating nests. Published 2019. This article is a U.S. Government work and is in the public domain in the USA.

KEY WORDS detection probability, grassland birds, nest searches, nest survival, prairie strips, sample size, thermal imager, thermographic camera.

Studies of nest success for birds are frequently used to provide demographic data necessary to develop conservation or management plans for species of interest. Birds that nest on the ground often rely on camouflage and concealment to protect their nests, making nests difficult for researchers to locate. Thermal imagers are hand-held cameras that have a sensor that detects emitted or reflected thermal infrared radiation (i.e., heat), displaying it as an image. By highlighting warm objects against cooler backgrounds, thermal imagers could allow researchers to locate cryptic bird nests containing incubated eggs or nestlings. Indeed, thermal infrared-imaging cameras have been explored as a method for locating warm bird nests since at least 1995 (Boonstra et al. 1995). Previously, researchers have explored the use of thermal-imaging cameras for locating nests of cavity nesters, tundra-nesting birds, grassland-nesting ducks, grassland-nesting sparrows, and ground-nesting forest songbirds with mixed success (Boonstra et al. 1995, Galligan et al. 2003, Mattsson and Niemi 2006). All studies published to date, however, have relied entirely on qualitative methods. To our knowledge, there are no published studies that quantitatively compared nest detection probabilities when a thermal imager is available to detection probabilities without a thermal imager.

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[1]*E-mail: mattstep@iastate.edu*

We searched standardized plots for bird nests with and without the availability of a thermal imager with the goal of estimating differences in nest detection probability when a thermal imager is available for use across the normal range of conditions during a field-day. Improving the detectability of cryptic bird nests in grass would allow researchers to increase sample sizes and thus statistical power to answer study questions.

STUDY AREA

Our study was conducted on 7 farms in central Iowa, USA, in the summer of 2016. Nest searches were conducted as part of a larger study examining nest survival in contour buffer-strip conservation features composed of diverse native vegetation, hereafter referred to as prairie strips as described by Schulte et al. (2016). Farms were selected for the presence of prairie strips and other grass conservation features and located within 100 km of Ames, Iowa.

METHODS

We searched for bird nests on 125 randomly selected plots at our 7 study sites. Search plots were stratified by property and land use with 25 plots/land use: row crop with no cover crop (20×100 m), row crop with cover crop (20×100 m), narrow (5.6–10.4 m in width) prairie strips, wide (15.2–77.7 m in width) prairie strips, and exotic cool-season grass strips (7.7–71.7 m in width). Search plots in linear grass features were the width of the feature and a variable length (7.4–178.2 m) to standardize the area at

0.1 ha. We anticipated crop plots to have lower densities of nests so we created them larger (20 × 100 m, 0.2 ha) to increase the probability of nonzero nest counts and placed them ≥50 m from a field edge.

We used a FLIR® E8 handheld model (FLIR® E8™; FLIR Systems Inc., Nashua, NH, USA) thermal infrared-imaging camera sensitive to 7.5–13 μm thermal radiation at a resolution of 320 × 240 pixels. It was sensitive to differences of <0.06° C, had an accuracy of ±2° C, and weighed 0.575 kg with a battery life of approximately 6–8 hr of intermittent use. It retailed for US$3,995. We operated the imager with the temperature color scale set so that background temperatures were presented as uniformly cool colors and only temperatures above a range approximately 32–40° C were displayed in a warm palette. This allowed the user to focus on temperature signals that could have originated from a living endothermic organism.

A pair of observers searched for nests in each plot for 3 min/0.1 ha once per week, alternating weeks with a second pair of observers. Searches were conducted by systematically walking through the plot and disturbing vegetation with a sweeping stick while watching for flushing adult birds (Martin and Geupel 1993, Winter et al. 2003). Once a flush was observed, indicating the possible presence of a nest, observers paused the plot search timer and conducted a secondary search of the area around the flush to locate the nest. Secondary searches included the area from which the observers thought the flush may have originated, as well as the area from which a bird may have run before flushing, typically 2–3 m around the spot of the flush, but up to a radius of approximately 5 m for some flushes. Observers timed secondary searches, which typically lasted 1–5 min or until the observers felt they were likely to have located a nest if one was present.

We used a double-observer approach to quantify nest detection probability. Nests located by one pair of observers were not marked or revealed to the second pair searching the following week, so that each pair's searches were independent. Upon initial discovery, the first pair of observers recorded the location of the nest with a high-precision Global Positioning System (GPS) unit (Trimble® GeoXT™ 2005 Series; Trimble Inc., Sunnyvale, CA, USA) and installed a small (17.35-mm diameter × 5.89-mm thick) autonomous thermal data logger (iButton® Thermochron® DS1921G; Maxim Integrated, San Jose, CA, USA) in the bottom of the nest cup to monitor nest temperature as an indication of nest status (Hartman and Oring 2006). We used GPS coordinates, nest substrate, and presence of a temperature logger in the nest to match nests found independently by both pairs. After plot searches were complete at a site for the day, each pair of observers conducted nest visits to determine if nests they had found the previous week were still active and had been available for detection by the second pair of observers. The proportion of nests known to be present and active that are found by the naïve second pair of observers was the detection probability of nests in plots and used in our larger study to estimate the density of nests on the landscape.

One of the pairs of observers carried the thermal-imaging camera and used it for secondary searches whenever environmental conditions allowed a warm nest to be distinguished from the thermal background (e.g., early in the morning or when the sky stayed overcast through the morning). Primary search methods were the same for both pairs of observers. Observers recorded start time and cloud cover for all plot searches. The pair of observers carrying the thermal imager also recorded maximum temperature displayed by the thermal imager. We took visual-obstruction readings (VORs) at the beginning and end of the field season to determine vegetation density in every plot. We measured VORs with a Robel pole, which we viewed from each cardinal direction from a distance of 5 m and a height of 1 m (Robel et al. 1970).

Plots were searched by only one of the pairs once per week, so nests located by the first pair had to survive for 6 days to be available to be discovered by the second pair. After plot searches were finished for the day, each pair checked on nests they had found in prior weeks. If a nest was still active, then we considered the search conducted in that plot that day by the second pair of observers to be an "eligible trial" (Smith et al. 2009). We included all eligible trials in the analysis, regardless of whether thermal-imager use was attempted. This allowed us to test the overall effect of adding a thermal imager to a field crew's toolkit and not just its use under ideal conditions.

We then classed outcomes from all eligible trials as either a redetection or nondetection and classified outcomes as a Bernoulli response variable in logistic regression models. We used likelihood ratio tests (LRT) to test for significance ($\alpha = 0.05$) compared with models with fewer parameters. We first tested eligible trials for an effect of availability of a thermal imager versus the null model. We also tested a model containing a factor for thermal-imager treatment and a factor for species against a model containing only a thermal-imager factor.

Direct sunlight at a high angle was likely to affect the ability of an observer to differentiate the thermal signal given by a warm nest and thermal signals created by reflected solar rays. To account for this, we tested a model with main effects for thermal-imager availability and minutes elapsed since sunrise plus an interaction term against a model containing only a factor for thermal-imager use.

Vegetation density in search plots was also likely to affect effectiveness of the thermal imager, so we modeled detection as a function of thermal-imager use plus average early season VORs across each search plot compared with thermal-imager use alone. We conducted all analyses with the statistical software Program R (Version 3.2.5, www.r-project.org, accessed 4 Apr 2016). This study was approved by the Iowa State University Animal Care and Use Committee (IACUC log #2-15-7960-Q).

RESULTS

We conducted 842 plot searches between 10 May 2016 and 27 June 2016, averaging 6.7 searches/plot over 7 weeks. Air temperature during searches varied from 6.0–34.1° C (mean = 22.5° C, median = 23° C) and cloud cover ranged from 0% to 100% (mean = 36.8%, median = 20.0%). We conducted plot searches between 0.5 hr before sunrise to 11 hr after sunrise, with the mean start time of 3.5 hr after sunrise.

We located 39 nests during plots searches. Using Program MARK (White and Burnham 1999), nests were estimated to have a daily survival rate of 0.89–0.90, which predicts that only 51–53% of them would survive the 6-day interval between the first and second checks. Based on information from the first pair of observers, only 24 nests were known to be present and active when the second pair of observers conducted a search, forming an eligible trial (Table 1). Eligible trials resulted in redetections for 3 of 13 nests when a thermal imager was available and for 1 of 11 nests when no thermal imager was available.

We found no differences between availability and no availability of a thermal imager (LRT: $\chi^2_{23} = 21.63$, $P = 0.35$). We had small sample sizes and a lack of redetections from some species for either search method (Table 1); therefore, we did not test for differences in detectability among species (dickcissel [*Spiza americana*], killdeer [*Charadrius vociferus*], red-winged blackbird [*Agelaius phoeniceus*], or vesper sparrow [*Pooecetes gramineus*]). We therefore assumed that detectability did not differ among species for subsequent tests.

Thermal signals from warm nests were clearer early in the morning, so we also tested a model that included main effects and the interaction between thermal-imager availability and time since sunrise against a model with thermal-imager availability alone. We found no evidence for an interaction between thermal-imager availability and time since sunrise (LRT: $\chi^2_{21} = 19.82$, $P = 0.17$).

We were unable to test VOR as a fully interactive effect with thermal-imager availability because the model did not converge.

Table 1. Outcomes of eligible trials of thermal-imager availability on nest detection probability, Iowa, USA, in 2016. Number of eligible trial outcomes ($n = 24$) for determining the effect of availability of a thermal imager on detection probability of bird nests by species, search method, and outcome. Eligible trials are defined as an opportunity by a second pair of observers to locate a nest that was known to be present and active based on information from the first pair of observers. Eligible trials were conducted on dickcissel, killdeer, red-winged blackbird, and vesper sparrow nests. Trials were conducted on commercial farms in central Iowa in the summer of 2016.

Species	Treatment	Redetection	Nondetection
Dickcissel	Thermal imager	1	2
Dickcissel	Traditional	1	3
Killdeer	Thermal imager	0	1
Killdeer	Traditional	0	0
Red-winged blackbird	Thermal imager	2	3
Red-winged blackbird	Traditional	0	2
Vesper sparrow	Thermal imager	0	4
Vesper sparrow	Traditional	0	5
Total		4	20

VOR as an additive effect did not improve the thermal-imager availability model (LRT: $\chi^2_{22} = 20.75$, $P = 0.76$).

DISCUSSION

Bird nests in grass areas are often cryptic and difficult to locate. In previous studies, effectiveness of thermal-imaging devices for locating bird nests was evaluated in a qualitative manner, but no studies have been published that used a rigorous designed experiment. We conducted such an experiment to test if having a thermal imager available for use when thermal conditions were appropriate (early in the morning or under heavy cloud cover) resulted in differences in detection rates for nests. We found no support to indicate there was a large difference in detection probabilities when a thermal imager was available for use.

Results from previous qualitative studies on use of thermal imagers have been mixed. Boonstra et al. (1995) were unable to locate the nests of 2 grassland-nesting ducks (*Anas crecca carolinensis, A. platyrhynchos*) whose approximate location was known, until they were within 1 m of the nest. They found nests of Arctic tundra birds such as Lapland larkspurs (*Calcarius lapponicus*) and pectoral sandpipers (*Calidris melanotos*) to be obvious once the general area was known from traditional methods. Galligan et al. (2003) found a thermal imager to be useful in pinpointing the location of nests of extremely cryptic *Ammodramus* sparrows once the general area was known from an adult flushing in response to rope-dragging. Mattsson and Niemi (2006) found 2 of 19 ovenbird (*Seiurus aurocapilla*) nests using a thermal imager. Both nests were located when the opening of the domed ground nests were oriented toward the observer using the imager. They did not have success using the thermal imager to locate any nests of other ground-nesting forest songbirds. Mattsson and Niemi (2006) found the thermal imager gave no advantage for finding nests when the adult birds did not give a behavioral cue to narrow the search area, and the telescope-like design of the imager they used limited its usefulness. Boonstra et al. (1995), Galligan et al. (2003), and Mattsson and Niemi (2006) all describe direct sunlight and obstruction by vegetation as factors limiting the usefulness of the imager for finding nests.

Our results included only 4 redetections from 24 eligible trials, an overall detection probability of 0.167. We conducted a power analysis and determined that with this sample size, detection probability would need to increase from 0.167 to 0.503 (an effect size of 3.01) to be detected in 95% of trials. This small sample size limited our ability to make inferences to potential strong effects only. We expect the thermal imager did not yield a strong improvement in detection rates for 3 reasons. First, only 40% of our plot searches and 46% of our eligible trials were conducted within 2 hr of sunrise or under >90% cloud cover. Reflected solar infrared rays under commonly sunny conditions made it very difficult to distinguish actual nests from background thermal noise (Fig. 1).

Secondly, an unobstructed line of sight was required between the nest and the thermal imager for the heat signature to be detected. Our search-plot treatments had a range of

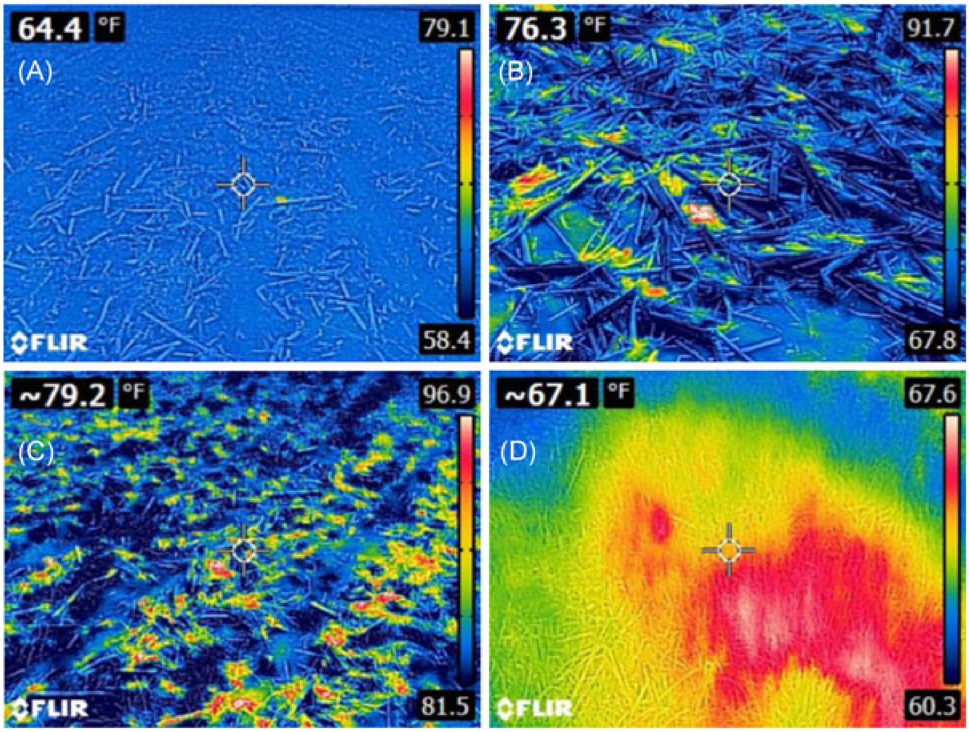

Figure 1. Example views through a thermal imager used to detect avian nests in Iowa, USA, during 2016. The temperature in the upper left is a measurement of the thermal energy being emitted or reflected from the object in the crosshairs, not the ambient air temperature. The red–blue scale on the right of each image shows the range of emissivity values represented within the field of view. (A) Vesper sparrow nest (just right of cross hairs) in a barren agricultural field before dawn. (B) Killdeer nest (just below and to the left of cross hairs) in a barren agricultural field within an hour after dawn. (C) Direct sunlight early in the morning reflects off many surfaces, creating a confusing image. There is no nest in this view. (D) Smooth brome grass monoculture with strong reflected solar rays in the early afternoon. There is no nest in this view.

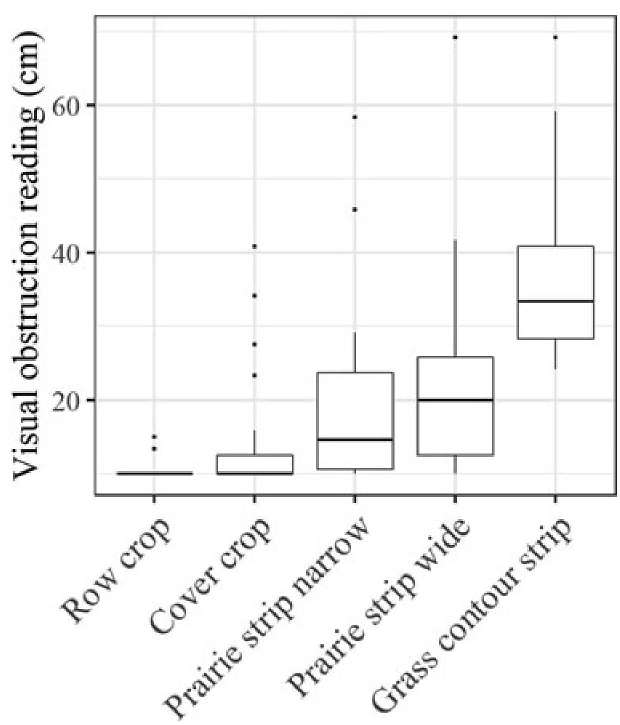

Figure 2. Vegetation densities of search plots for grassland avian nests in Iowa, USA, during 2016. Vegetation densities measured by visual-obstruction readings (VORs) by plot type. VORs were measured in May of 2016 to estimate vegetation density at the start of the nesting season. Many of the prairie strip plots were newly established and had been mowed for weed control the previous year, accounting for the relatively low VOR readings. Boxes represent the inter-quartile range (IQR), lines indicate mean values, whiskers indicate values within ±1.5 IQR, and dots are outliers beyond those values.

vegetation densities measured as VORs in May, with median values varying between 10 cm for the crop field plots and 33.3 cm for the cool-season contour strip plots (Fig. 2). Vegetation density in the grass and prairie strips was relatively low at the beginning of the season, but increased substantially as the season progressed, especially in the prairie strips.

Finally, our study was designed as a practical test of the effectiveness of adding a thermal imager to our toolbox of existing nest-locating techniques and not a test of its effectiveness only under ideal conditions. If we had tested only under ideal conditions, it is possible that nest detection probabilities would have been greater using the thermal imager, but we would not have adequately addressed the overall effect on number of nests found. Because our motivation behind using a thermal-imaging device was to increase our sample size, we did not find the thermal imager we tested to be an efficient use of research funds.

The thermal imager in our study cost nearly US$4,000. Other models were also available that ranged in resolution from 80×60 to $1{,}024 \times 768$ pixels or more, and in price from US$500 to tens of thousands of dollars. We selected the FLIR® E8 based on its heads-up use and a balance of resolution, robustness, and price. It is possible that a more expensive unit may have performed differently and results of our case study are applicable only to units with similar specifications to the FLIR® E8.

Instead of purchasing a moderately priced thermal imager to increase the number of nests in our sample, we could have instead spent the same amount of money and hired an additional research technician for 400 hr. During 2 field seasons in 2015 and 2016, our field crew spent 3,520 hr with the primary goal of locating nests. During that time, we located 537 nests for our larger study. This equates to locating nests at a rate of 1 nest/6.5 hr of technician time (including transportation to and from sites and other non-searching tasks), or 61.5 nests/400 technician hours. An effect on nest detection probabilities of up to 3.01 times could have been present without detection in >5% of trials. Replacing 400 technician hours with the purchase of this model of thermal imager could therefore have resulted in discovery of between 246.9 fewer or 123.9 more nests. Even when considering that the thermal imager could be used across multiple field seasons, the additional technician hours would have had a more certain effect on our sample size than purchasing a thermal imager for use under limited searching conditions.

Although neither minutes elapsed since sunrise (representing the strength of reflected solar radiation) nor VORs were significant effects in our models, our experience operating the imager suggested that direct sunlight and visual obstruction were the 2 key limiting factors for pinpointing bird nests. This conclusion is consistent with the qualitative descriptions given by Boonstra et al. (1995), Galligan et al. (2003), and Mattsson and Niemi (2006).

While acknowledging that our statistical power was limited, we did not find that having a thermal imager available changed nest detection probabilities by >3.01 times. A thermal imager may improve detection probabilities by <3.01 times or may prove a valuable research tool in other study systems where observers spend more time searching for nests with no direct sunlight, such as before sunrise, under heavy cloud cover, under tree canopies, in shaded valleys, or in areas with very low vegetation, such as tundra or sparsely vegetated forest floors. More sensitive thermal-imager models could also be more effective at highlighting small warm bird nests from a greater distance. Further quantitative studies are needed to determine if differences in detection probability exist at less than the 3.01 effect size or if study niches exist where the thermal environment is more favorable for use of a thermal-imaging device in locating bird nests.

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ORCID

MATTHEW D. STEPHENSON http://orcid.org/0000-0001-8702-8556

LITERATURE CITED

Boonstra, R., J. M. Eadie, C. J. Krebs, and S. Boutin. 1995. Limitations of far infrared thermal imaging in locating birds. Journal of Field Ornithology 66:192–198.

Galligan, E. W., G. S. Bakken, and S. L. Lima. 2003. Using a thermographic imager to find nests of grassland birds. Wildlife Society Bulletin 31:865–869.

Hartman, C. A., and L. W. Oring. 2006. An inexpensive method for remotely monitoring nest activity. Journal of Field Ornithology 77:418–424.

Martin, T. E., and G. R. Geupel. 1993. Nest-monitoring plots—methods for locating nests and monitoring success. Journal of Field Ornithology 64:507–519.

Mattsson, B. J., and G. J. Niemi. 2006. Using thermal imaging to study forest songbirds. The Loon 78:74–77.

Robel, R. J., J. N. Briggs, A. D. Dayton, and L. C. Hulbert. 1970. Relationships between visual obstruction measurements and weight of grassland vegetation. Journal of Range Management 23:295–297.

Schulte, L. A., A. L. MacDonald, J. B. Niemi, and M. J. Helmers. 2016. Prairie strips as a mechanism to promote land sharing by birds in industrial agricultural landscapes. Agriculture, Ecosystems & Environment 220:55–63.

Smith, P. A., J. Bart, R. B. Lanctot, B. J. McCaffery, and S. Brown. 2009. Probability of detection of nests and implications for survey design. Condor 111:414–423.

Stephenson, M. D. 2017. Quantifying methods to improve statistical power in grassland and passerine bird nesting studies. Thesis, Iowa State University, Ames, USA.

White, G. C., and K. P. Burnham. 1999. Program MARK: survival estimation from populations of marked animals. Bird Study 46:S120–S139.

Winter, M., S. E. Hawks, J. A. Shaffer, and D. H. Johnson. 2003. Guidelines for finding nests of passerine birds in tallgrass prairie. Prairie Naturalist 35:197–211.

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